Large Room Meeting I (Chapter 22.7 & 24.1)

Major Goals

- □ Explain light phenomena using the particle model and wave model of light.
- □ Explain light interference using the wave model of light.
- □ Derive an expression for the location of bright spots in an interference pattern.

Need to Know

Imagine you shine light on a wall – the wall reflects light and you see a bright spot. Is it possible to shine light from two sources directly on the same spot on the wall and that spot to be dark?

Two Models of Light

- Particle Bullet Model – Light behaves like a stream of small, lightweight particles moving very quickly.
- Wave Model – Light behaves like waves.

How would each model explain the following light phenomena: Shadows, Reflection, Refraction?

Particle Bullet Model – Shadows

Particle Bullet Model – Reflection

Particle Bullet Model – Refraction

Wave Model – Reflection and Refraction

But Which Model is "right"?

Read and Interrogate
Read and interrogate section 22.7 (704 – 705).

24.1.0 – Observational Experiment
Observe what happens when water waves pass through a barrier with two small openings in this video.

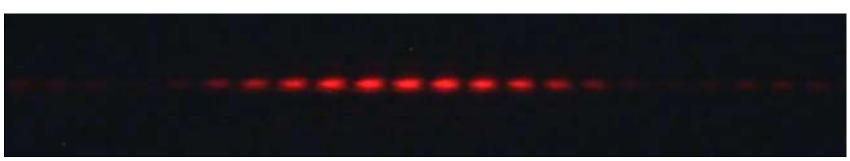
What do you notice about the wave that comes out of the two slits? Use what you know about waves to explain the outcome of this experiment.

24.1.1 – Observational Experiment
Now observe what happens when a laser beam is sent through a barrier with two very small openings in this video.

Can you explain the outcome of this experiment using the particle model of light?
(*Hint:* What would happen if you threw a bunch of tennis balls at two narrow windows)

Can you explain the outcome of this experiment using the wave model of light?
(*Hint:* Think about what we saw when water waves were passed through two similar slits)

24.1.2 – Explain



Why were there dark spots between each bright spot in the pattern we observed in the last experiment?

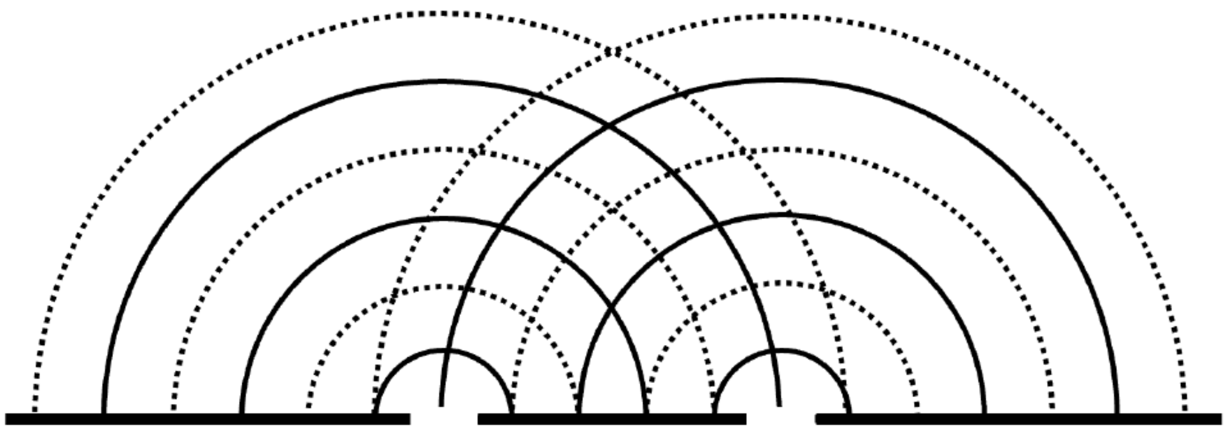
Is there any reason there should be specific locations where light particles can't end up?

Is there any way that two light waves could cancel each other out at specific locations?

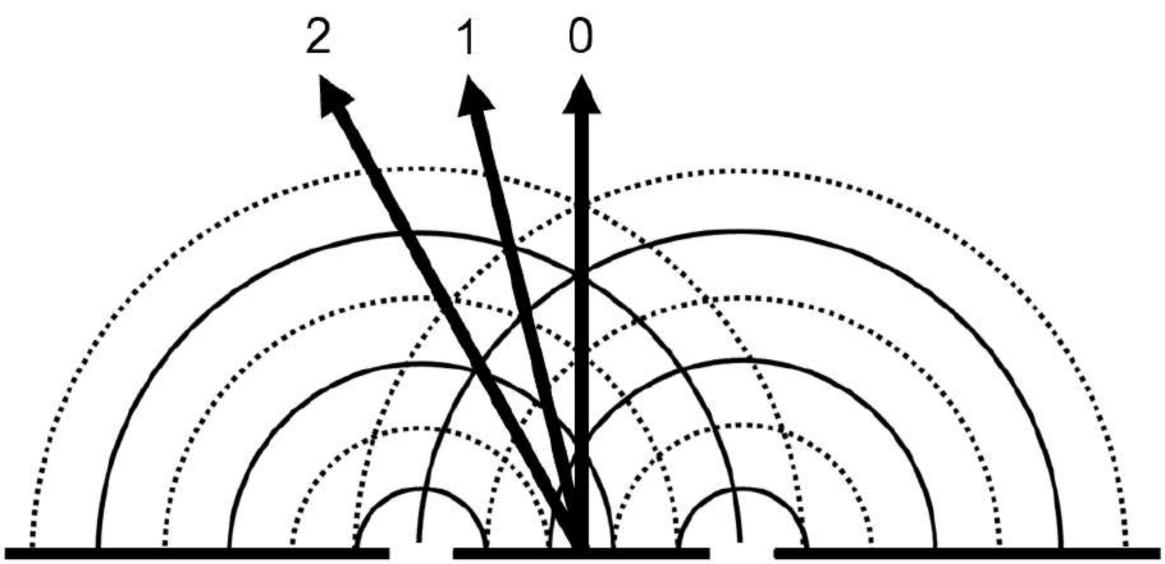
24.1.3 – Represent and Reason

The picture below shows the wavefronts that emerge from a pair of slits. The solid lines represent crests while the dashed lines represent troughs.

Mark each position where two crests intersect (cc), two troughs intersect (tt), and where a crest intersects a trough (ct)



Imagine this represents a water wave. What would you feel if you were standing somewhere along line 0 as the waves move past you? What about if you were standing on lines 1 or 2?



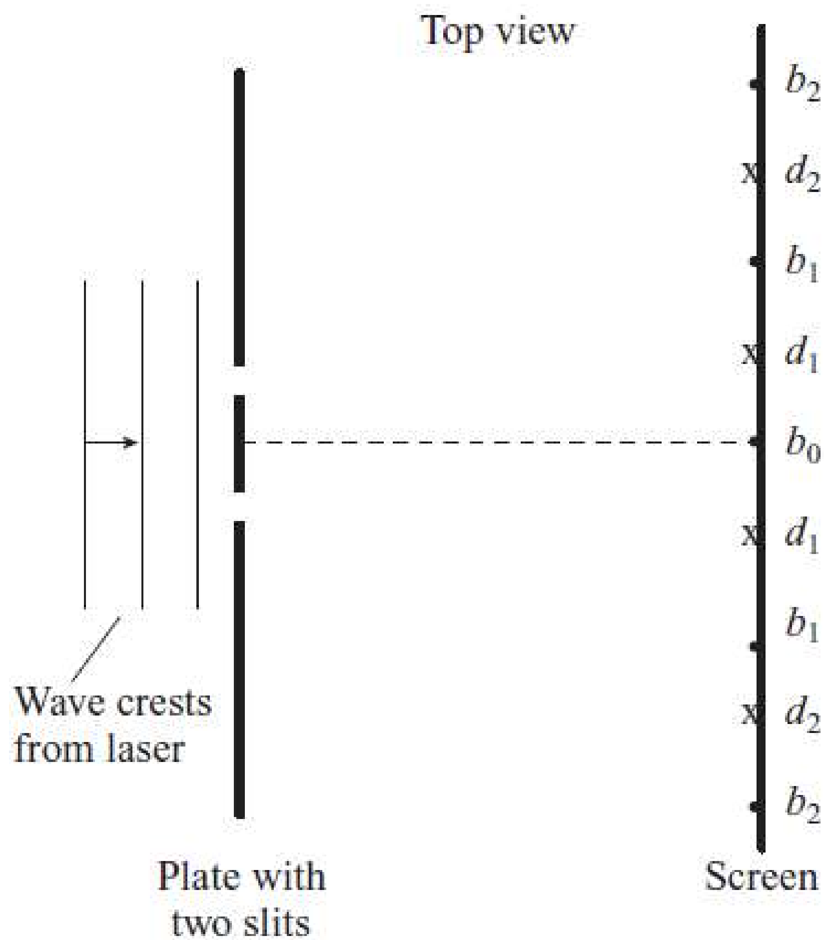
Now imagine this represents a **sound wave**. Would the sound be loud or quiet along each line?

Now imagine this represents **light**. Would the light be bright or dark along each line?

What we've Learned

24.1.4 – Represent and Reason

The image below shows the location of all the bright spots (b) and dark spots (d) due to light passing through two slits.



Explain why the center band b_0 is bright. (*Hint:* What do you know about the distance the wave from each slit has to travel to reach that point?)

Explain why b_1 above and below the center band are bright.

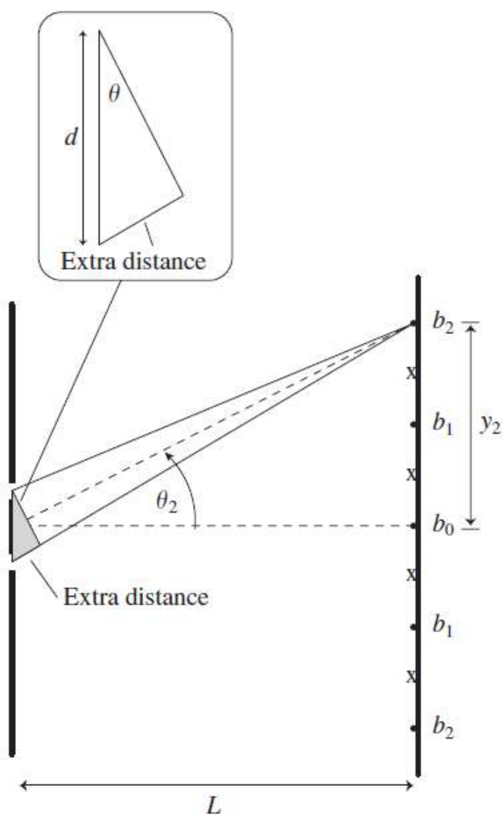
Explain why b_2 above and below the center band are bright.

Explain why d_1 above and below the center band are dark.

Explain why d_2 above and below the center band are dark.

24.1.5 – Deriving an Expression

We want to derive a mathematical expression for the locations of each bright spot in this interference pattern.



1. What is the extra distance the wave coming from the bottom slit needs to travel to reach point b_2, knowing that it is the 2nd point where constructive interference occurs? Express this distance in terms of the wavelength of the light.

2. How is the angle θ (shown in the inset) related to θ_2 shown in the main figure? Explain.

3. Write an expression that relates the extra distance that light travels from the lower slit to the b_2 bright band and the distance from the upper slit to that bright band expressed through the wavelength λ , slit separation d, and the angle θ in the triangle. Use the ***small angle approximation*** ($\tan\theta = \sin\theta = \theta$)

4. Write another expression that relates the angle θ_2 to the distance L from the slits to the screen and the distance y_2 from the b_0 central maximum to the position of the bright spot. Use the ***small angle approximation*** ($\tan\theta = \sin\theta = \theta$).

5. Combine these two expressions to find the distance y_2 from the central maximum to the position of the 2nd bright spot.

24.1.6 – Testing Experiment
If the equation we just derived is correct, what should happen when we ***decrease*** the distance *d* between the two slits?

Once you have made your prediction, watch the outcome of the experiment here. Record the outcome and compare it to your prediction.

What We Have Learned

Read and Interrogate
Read and interrogate section 24.1 (752 – 756).

Practice

A red laser is shone through a double slit apparatus with a slit separation of $d = 0.050$mm onto a screen $L = 2.0$m away. The first bright spot in the interference pattern is measured to be at $y_1 = 2.75$cm.

1. From this information, determine the wavelength of red light.

2. Predict the location of the first bright spot if instead we use green light with a wavelength of $\lambda_{green} = 550$nm.

3. Predict the location of the first bright spot if we use red light but a new slit apparatus with a separation of $d' = 0.030$mm

Small Room Meeting (Chapter 24.1)

Major Goals

- □ Use the equation for double slit interference to solve problems.

Student Instructional Ratings Survey

Please fill out the Student Instructional Ratings Survey for your recitation section at the following link: https://sirs.ctaar.rutgers.edu/blue. Pay close attention to the wording of the two new online learning questions:

- Despite the abrupt change to remote instruction due to the Covid-19 disruption, the instructor offered an effective learning experience in this course:
  A. Strongly Disagree. B. Disagree. C. Neutral D. Agree. E. Strongly Agree

- The move to remote instruction, due to the Covid-19 response, adversely (**i.e. negatively**) impacted my learning in this course:
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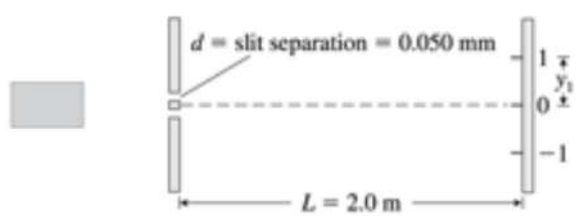
Question #1 (Quantitative Exercise 24.1) (Clarity and Evaluation)

You repeat the experiment described in Table 24.2 using slits separated by d = 0.050 mm and a screen at L = 2.0 m from the slits. This time, you use a green laser instead of a red laser. The second maximum (m = 2) appears on the screen at y_2 = 4.4 cm from the center of the 0[th] order maximum. Determine the wavelength of this light.



Question #2 (Chapter 24 Problem #3) (Clarity, Consistency and Evaluation)
Blue light of wavelength 440 nm is incident on two slits separated by 0.30 mm. Determine (a) the angular deflection to the center of the 3^{rd} order bright band and (b) its distance from the 0^{th} order band when light is projected on a screen located 3.0 m from the slits. (c) Draw a sketch (not to scale) that schematically represents this situation and label all known distances and angles.

Criterion	**Perfect (2)**	**Needs some work (1)**	**Needs a lot of work (0)**
Clarity	The solution is clear, expressed in words and symbols, takes no effort to comprehend.	The words are lacking but the symbolic part is clear. Takes some effort to comprehend.	Takes a lot of effort to comprehend. There is only math, mostly numbers, not general equations and there are no words explaining the thought process.
Consistency	Two or more different representations are present, they are correct and consistent with each other.	Two or more different representations are present and they are consistent but there are mistakes in representations.	Mistakes in representations or different representations are inconsistent with each other.
Evaluation	The answer is evaluated using at least two of the methods listed below: unit analysis, extreme case analysis, reasonability of the answer, consistency of representations.	The answer is evaluated using only one of the methods listed in “Perfect”.	There is no evaluation or there are serious mistakes in the evaluation (wrong units, misunderstanding of how reasonable numbers are).

Large Room Meeting II (Chapter 24.5-24.7)

Major Goals

- □ Apply your knowledge of lenses to predict how cameras and human eyes work

Need to Know

If you look carefully at the interference pattern we get from two slits we saw last semester, you will notice that there are unexplained drops in brightness. What causes this?

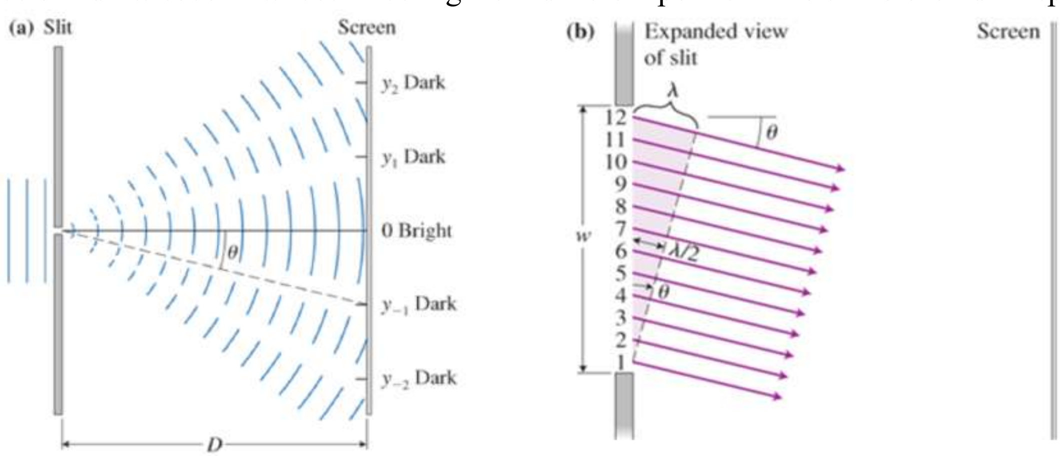
24.5.0 – Observational Experiment

Watch what happens light passes through a single small opening in this video. Record your observations.

24.5.1 – Represent and Reason

What happens to the light when it passes through the slit? Why does it spread out at all?

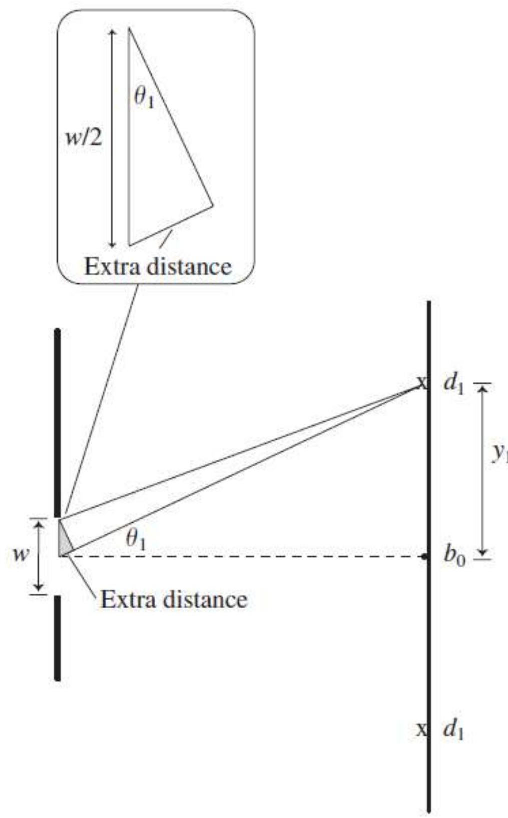
Each point on a wavefront can be treated as a source of new waves (Huygen's Principle). For this reason we can draw several waves traveling from different points in the slit to each dark spot.



What extra distance does the wavelet coming from the middle of the opening have to travel in order to cancel out the wavelet coming from the very top of the slit?

From this, write an expression which relates the angle θ_1 to the width of the slot w and the wavelength of the light λ.

Now write an expression which relates the angle θ_1 to the distance from the center to the first dark spot y_1 and the distance to the screen L.



What We Have Learned

Read and Interrogate
Read and Interrogate Section 24.5 pages 768-771.

24.5.1 – Testing Experiment
Use what we have learned to predict how the diffraction pattern from a single slit will change as the size of the slit ***decreases***. Sketch the patterns created by three different slit sizes.

Compare your prediction to the outcome shown in the slides.

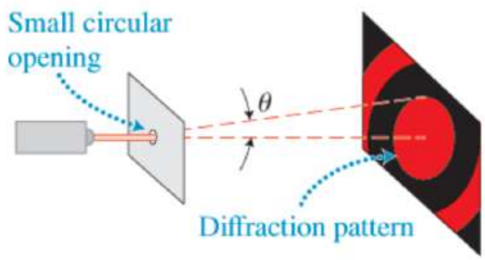
24.5.2 – Represent and Reason

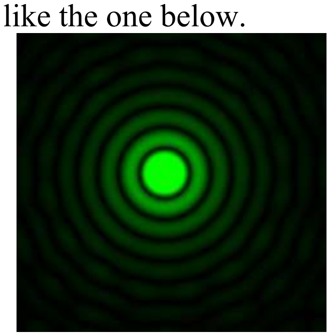
A screen is placed 1.0m away from an apparatus with slits of various widths. A red laser with wavelength 650nm is shown through slits of each of the following widths: 0.5mm, 0.3mm, and 0.2mm.

	0.5 mm	0.3 mm	0.2 mm
Sketch Diffraction Pattern			
Location of 1st Dark Spot			
Location of 2nd Dark Spot			

Diffraction Through a Circular Opening

A circular opening will produce a circular diffraction pattern like the one below.





$$\sin\theta = \frac{1.22\lambda}{D}$$

What About Our Eyes?

Think about how light travels from objects around us to our retinas. Is there any point at which we should be concerned about diffraction?

What Happens if Two Objects are Too Close

If two objects are so close together that the diffraction patterns produced by their light as it passes through an opening overlap, it becomes impossible to perceive them as two separate objects. We cannot ***resolve*** them.

Resolution of the Eye

The diameter of a pupil in bright light is somewhere between 2mm and 4mm. Two dots are drawn on a piece of paper with an orange pen $\left(\lambda_{orange} = 600\text{nm}\right)$ 1cm apart. From this information, estimate how far a person would need to stand from this paper before they can no resolve the two dots as separate.

24.7.2 – Regular Problem

Monochromatic light passes through two slits and then strikes a screen. The distance on the screen between the central maximum and the first bright fringe at the side is 2.0 cm.

Draw a sketch of this situation, labeled with all given information.

Determine the fringe separation if the slit separation is doubled and everything else remains unchanged.

Determine the fringe separation if the wavelength is doubled and everything else remains unchanged.

Determine the fringe separation if the screen distance is doubled and everything else remains unchanged.

Diffraction Patterns from Obstructions

Light passing around a small obstruction will produce the same diffraction pattern as if the light were passing through an opening with the same width as that obstruction. This is called ***Babinet's principle***.

Using this knowledge, I was able to create a diffraction pattern by shining a red laser pointer at a single strand of my cat's hair while standing 1.0 m away from the wall. The laser has a wavelength of 670 nm and the distance from the center of the pattern to the first dark spot was 1.2 cm.

Use this information to find the width of my cat's hair.

Read and Interrogate

Read and Interrogate section 25.7 (774 – 776)

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